Plant Food

Its Sources, Conservation, Preparation and Application

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The Needs of Modern Farming

AN ACRE OF TILLAGE LAND eight inches deep weighs 2,000,000 pounds (1,000 tons). In the East the average dressing of concentrated fertilizer is 1,000 pounds per acre where no manure or "cover crop" or "catch crop" is plowed in. To the Western farmer who uses from 400 to 800 pounds per acre, 1000 pounds seems large, but it gives only *one pound of mixed fertilizer to every ton of soil*, or less than a grain of actual plant food to each pound of soil. This infinitesimal amount combined with the "natural yield of the land" has been known to produce under favorable weather conditions 400 bushels of potatoes, 100 bushels of shelled corn, or 30 to 40 tons of ensilage per acre; *to produce profit in place of loss; to turn failure into success, and still leave the soil no poorer, but in most cases much richer.*

Results from Small Applications

It seems almost a miracle of nature, but these results have been produced so often, in so many places and for so many years, that they are no longer unusual. They are realities to be depended upon as surely as seed-time and harvest return.

Available Plant Food the Key

Successful crop growth rests, as we all know, primarily on a rich soil—that is, available fertility or *available plant food.* When the available plant food is exhausted, then it must be supplied in one way or another in order to secure satisfactory returns. It is a case of give and take. The crop says in effect, "Feed me and I will feed you," and while it is very exacting in its demands, yet it is generous in its returns. Supplied with less than half a grain of actual plant food to each pound

of soil, it will return a million or ten million-fold in food for man and beast. Thus it is obvious that living, growing crops, like living, growing animals, must be supplied with food, either from natural sources or by the skill of man.

To aid in supplying the need of "plant food" is the reason for the existence of the fertilizer industry—an industry which is based on all the sciences that relate to soil and crop problems; on geology, which tells of the formation and composition of soils; on chemistry, which shows the needs of crops and how they can be supplied; on botany, which tells of the structure of crops and habits of growth, and, finally, on bacteriology, a comparatively new science, which tells of the soil bacteria, or "yeast of the soil"—the lower orders of life, without which crops cannot thrive. This latter science, which we are just beginning to develop and understand, is completely overturning our preconceived notions of drainage, tillage and the relations of plant food ingredients to crops and soils.

What the Sciences Contribute

Thus it will be seen that the man who is carrying on the fertilizer industry today and the farmer who is more or less dependent on that industry for a part or all of his plant food must each be more or less familiar with these subjects to meet the needs of modern and successful farming.

The Modern Idea of Plant Feeding

It is admitted that fertility is the corner-stone of agriculture, as agriculture is the corner-stone of all other industries. Fertility—that is, *available plant food*—is what *nature or man prepares* for plants which are now grown as food crops for the support of humanity.

Formerly the practice was to manure the soil in order to restore lost fertility and to supply, by guesswork, deficiencies in the soil, as ascertained by a chemical or a crop analysis of the soil. This method is not now regarded as a practical solution of the problem, for neither chemical analysis nor the growing of crops can be relied upon as a true guide to its enrichment. The chemical analysis of the soil discloses too much that is misleading, and the growing, or even the matured crop, too little that is conclusive.

Analysis of Soil no Guide

Modern practice teaches that it is not the soil, but the crop, that we should first consider. In a word, we have turned from

the soil which cannot positively answer, full though it is of life, to the living crop which can; so today we feed the crop rather than the soil. In the modern sense, therefore, the farmer is a manufacturer and the soil is his machine, into which he puts plant food and out of which, by the aid of nature, including the bacteria and other seen and unseen forces, combined with his own efforts, he takes his product at harvest time. If the soil machine is a good one—that is, of the right texture and retentive of plant food, full of active nitrifying bacteria or "yeast"—so much the better. If it has a balance of crop-producing power to its credit, we seek to preserve that balance for an emergency, as the prudent man preserves a balance in the bank in case of need.

Feed the Crop, Not the Soil

In stock feeding we chiefly concern ourselves with a study of the animal and its needs. So in plant feeding we must make an intelligent study of the needs of the living crop, and in the study of this problem we must also study the soil, its latent or potential fertility, its physical and chemical characteristics, and particularly the lower orders of life which it contains, the bacteria and other unseen forces, to the end that we may know what each contributes to the upbuilding not alone of the soil, but of the crop life above the soil, upon which all higher forms of life and activity depend.

What to Study

Our problem then is not only to conserve, but to supply the balance of ready plant food required by the growing crop, as milk or prepared food is supplied to the growing child.

What Plants Need

Without going into an elaborate analysis of plants, let us come immediately to consider their chief needs and the chief deficiencies of all soils that have been farmed for some time. To ascertain what plants need, we must first know what they are composed of. Professor Brooks aptly illustrates the matter in this way: 100 lbs. of green grass, thoroughly dried in the sun, will shrink to about 25 lbs., the loss of 75 lbs. being water. If the 25 lbs. is put in an oven and heated to 212° (boiling point of water), we can drive off from 12 to 14 lbs. more, or from 86 to 88 lbs. of water in all. The perfectly dry, remaining portion is called by the chemist "*organic* matter." If these 12 or 14 lbs. of organic matter are burned, there will be left from 1 to 3 lbs. of

ashes, which the chemists call "ash," or *in*organic matter. Generally speaking, therefore, we find that 100 lbs. of green crops consist of:

Water	**85 to 90 lbs.**
Organic Matter . . .	**10 to 15 lbs.**
Which consists of:	
Carbon	
Hydrogen	
Oxygen	
Nitrogen	
Inorganic Matter (Ashes) .	**2 to 3 lbs.**
Which consists of:	
Phosphorus	
Sulphur	
Potassium	
Calcium	
Magnesium	
Iron	
Sodium	
Chlorin	
Silicon (Sand)	

It would appear from the foregoing table that water is the largest factor in growing all crops, but unfortunately, in general farm practice, the farmer is dependent upon the rains to supply it. It is a factor beyond his control except by irrigation. It is known that thorough tillage will conserve moisture in the soil and is absolutely essential in dry seasons, hence constant and thorough cultivation is the basis of successful "dry farming" in arid regions where water is not obtainable.

Nitrogen Abundant but not Available

The organic matter we observe is composed of carbon, hydrogen, oxygen and nitrogen. Now the first three are supplied in abundant quantities through the air and water by the aid of sunshine, which in nature's laboratory converts these elements into the structure of the plant, which we know as stalk, leaf or straw; also as starch in the potato and grain, or sugar in the fruit. It is a curious fact of nature, however, that while nitrogen is the largest constituent of air, being four-fifths of its volume (equal to 35,000 tons over every acre of soil), yet it is not directly available to general farm crops. It is not positively known that any crop can extract nitrogen from the air except the clover family, which, through nodules on the roots, absorbs nitrogen from the air in the soil.

Man inhales air, composed principally of nitrogen and oxygen, and exhales nitrogen and carbonic gas, the latter of which contains carbon. Plants absorb the carbonic acid gas from the air, retain the carbon and exhale oxygen, but they have no power of appropriating through the leaves any part of the abundant supply of nitrogen which surrounds them in the atmosphere. The nitrogen which they require must be obtained, except in the clover family, from decayed or decaying organic matter in the soil—which contains nitrogen, as we have seen,—the accumulation of decayed roots and leaves in virgin soils for ages and which is often designated as humus. When the available nitrogen from these virgin or natural sources is exhausted, it must be obtained from artificial sources or by plowing in green crops.

Carbon and Oxygen

The inorganic matter, or ash group, we find to consist of a number of minerals, all of which are present in available forms in most soils, excepting phosphorus (phosphate of lime), potassium (potash), and calcium (lime). Experience shows that if we supply the phosphorus in the shape of phosphate of lime, the characteristic and predominating element of bone, and potash in the form of ashes or in the form of potash salts found in nature, and sometimes a little lime to sweeten the soil and occasionally some sand in the case of peat soils, we are supplying the important constituents, or the "little balance," that is necessary for successful crop production. Therefore, to sum up the problem, through analyses of crops, analyses of soils, and experiments, also through practical farm operations conducted for more than half a century, it has been observed that the *three essential things* to be supplied in all commercial manures are nitrogen, phosphoric acid and potash.

The Little Balance

The Three Essential Elements of Plant Food

Nitrogen, the First Element

Of the three essential elements of crops (nitrogen, phosphorus and potash) which the farmer must supply, we place nitrogen first in the group, not because it is the most important, but because it is relatively the least abundant in an available form and therefore the most costly. As we know, there is an inexhaustible supply of nitrogen over every acre of soil, and why nature arranged that it should not be available to the great family of plants is an interesting question for scientific speculation and investigation.

Nitrogen (N being its symbol in chemistry) is known in the trade as ammonia, the terms being used interchangeably. As a matter of fact, ammonia is a combination of nitrogen and hydrogen (NH_3), that is, one part nitrogen to three parts hydrogen, 100 lbs. of ammonia containing 82 lbs. of nitrogen. The form of ammonia that is best known is hartshorn, which is water and ammonia combined.

What NH_3 Means

Nitrogen is a gas without color, odor or taste. As plants cannot absorb it directly from the atmosphere, it must be added in the manure or fertilizer applied. Except in the air it always exists in combination with some other element, and yet it is always hastening back to the state of single-blessedness, to the pure nitrogen of the atmosphere through the process of nitrification or decay.

Sources of Nitrogen

The sources of nitrogen are the humus of the soil, animal manures, and what are known as organic ammoniates, such as packing-house refuse, tankage, dried blood, and fish waste or scrap, also the seeds of plants such as cotton-seed or linseed. Then there are chemical sources, chiefly nitrate of soda (a natural deposit found in South America), and sulphate of ammonia, a chemical by-product made by gas and coke works. Some soft

coals contain as much as 30 lbs. of nitrogen to the ton, and if it could all be extracted, such coals would be worth more for their nitrogen than for use as coal.

Why It Is Needed

Nitrogen is needed in the plant to form the protein of the plant and seeds or grains; and these in turn, when eaten by animals, form the protein of the meat, muscles and tendons, steak and chops, the white of eggs, etc. Nitrogen also imparts a green color to the leaf, makes it larger, richer and more luxuriant in appearance. An excess of nitrogen will produce a soft, pulpy growth which will fall down, while the lack of it is shown in a spindling, sickly, yellow growth.

Why It Forces Growth

Nitrogen is sometimes described as the alcohol of fertilizers, the stimulating property, but as there is no food stimulant known to plants in the sense that alcohol is a stimulant to man, this assumption is erroneous. It forces growth because it is usually applied in water-soluble or very available forms like nitrate of soda, sulphate of ammonia, or in the form of acidulated organic matter like dried blood, tankage, fish, etc. Untreated horn shavings, although rich in nitrogen, will not force growth, nor will nitrogen in any form do it unless there are present in the soil nitrifying bacteria to convert the organic matter into nitric acid which the plant can then absorb. Neither will nitrogen force growth unless soil conditions are right and there are also present the phosphates and potash to keep it company.

When crops "lodge" or "fall down," it is often the result of over-feeding of nitrogen, which forces the growth faster than the plant can obtain or assimilate the silicates, especially silicate of potash, necessary for stamina. This often happens on rich muck soils, and it is on such soils that an application of potash and sand is essential to correct this condition.

When Nitrogen Won't Work

One can put coal in a stove, but unless air containing oxygen is admitted, it will not burn. Air depleted of its oxygen and admitted to a stove would put out whatever fire was started; so nitrogen will not work in the soil unless the conditions are right for it to be oxidized, so to speak, and converted into available form. Coal will not burn in a chimney which is stopped up. A soil stopped up with water or baked from lack of cultivation or insufficient humus (organic matter) will not grow a crop, no matter how much nitrogen or other plant food ingredients are applied.

Nitrogen is no more important in the chain "than the weakest link thereof," and yet it is so rare an article, the commercial sources of it being so few, that he who will discover a cheap commercial process for obtaining it from the atmosphere and combining it in a form that will be serviceable in crop production, not only will be a great benefactor and inventor, but will change the economy of living on this earth.

Phosphoric Acid, the Second Element

What Is P_2O_5

Phosphoric Acid (P_2O_5) is the characteristic element of bone. Its office in plant feeding is primarily to furnish phosphorus to plants, especially to their grains and seeds. No grain or seed could be formed without it, although it is found in the stalks and leaves. As we know, the skeleton, or framework, of men and of animals is bone, in which there is 13 per cent of phosphorus. As grains and seeds constitute in some cases the chief food of animals and of men, nature has provided that phosphorus shall be one of their important constituents. In other words, as we trace back the structure of animals to plants, and of plants to plant food ingredients, we find those ingredients to predominate in virgin soils which are necessary for, and which predominate in, the structure of animals or men.

What It Does

In addition to supplying phosphorus, soluble and available phosphoric acid seems to have a stimulating influence on the feeding capacity of plants and on the soil. It seems to be a "mixer" and a promoter of plant assimilation and digestion. On that account it hastens maturity in many cases. For example, soluble phosphate of lime is almost a specific for certain root crops like turnips and beets, and yet phosphorus does not enter largely into the composition of these crops. Besides supplying phosphorus to the kernel of corn, soluble phosphates of lime are absolutely essential in the hastening of the maturity of the corn crop. Phosphoric acid in the form of phosphate of lime also constitutes a splendid base upon which to build a complete fertilizer. In the form of acid phosphate (phosphates of lime dissolved in sulphuric acid), it constitutes in many cases the "bulk" of commercial fertilizers, which is referred to elsewhere.

We do not find phosphorus or phosphoric acid in an uncombined form in nature, but always united with some base or alkali, chiefly with lime in the form of phosphate of lime.

The mother source of phosphate of lime is supposed to be the mineral known as apatite and found in various parts of the world. Other mineral sources of phosphate of lime have been found, more particularly in South Carolina, Florida and Tennessee. All soils contain an abundant supply of phosphate of lime, but as we have exhausted the *available* part, we must supply it in some form or other.

Source of Phosphoric Acid

The original commercial source was bone, which is composed of about 65% of phosphate of lime, the other 35% of the bone being cartilage, fat, marrow, glue, water, etc. After the demand for fertilizer had exhausted the supply of bone, the mineral deposits of phosphate of lime were taken up, and it was found that by grinding them fine and dissolving them in oil of vitriol (sulphuric acid), the phosphate of lime was rendered available to plants, and thus it helped to supply the "little balance" of this ingredient necessary for crop production. The sources of phosphorus (phosphoric acid) and phosphate of lime are therefore the bones from packing-houses, fisheries and market places and the mineral deposits of phosphates in all parts of the world.

Bone, Composition of

It is believed that phosphoric acid is the most important of the three principal elements of plant food, not because it is the most required, for in the composition of the plant it is least needed, but because it is a "catalyzer" as well as a fertilizer. In chemistry, a catalyzer is an element which assists in the union of other elements without becoming a part of the union—a sort of "go-between"; that is, besides furnishing the needed phosphoric acid, it assists in the diffusion and assimilation of other plant food ingredients. If phosphoric acid exercises a catalytic action in the soil (and there is no doubt of it), the experiments of Lawes and Gilbert, as well as results in practical crop growing, indicate that *it is the soluble phosphoric acid which possesses this quality*, and that the *insoluble phosphoric acid does not possess it at all.* This in part explains why superphosphates (dissolved bone, dissolved bone black and acid phosphate) are much superior to undissolved phosphates.

What Is a "Catalyzer"

Four Forms of Phosphate

There are four forms of phosphate of lime, as follows:

4-lime phosphate—Tetra-Calcic—A by-product of steel manufacture.
3-lime phosphate—Tri-Calcic—Mineral phosphates and bone.
2-lime phosphate—Di-Calcic—Reverted phosphoric acid.
1-lime phosphate—Mono-Calcic—Water soluble phosphoric acid.

The last two phosphates, 1-lime and 2-lime, are what constitute the "available" phosphoric acid in acid phosphate, dissolved bone black and in chemically prepared fertilizers.

Liebig's Discovery

Liebig, the founder of agricultural chemistry and the father of the chemical fertilizer industry, discovered that if we treated bone, a 3-lime phosphate, with sulphuric acid, we robbed it of two parts of its lime and that the remaining one part was soluble in water, in which form plants could readily absorb it, and in which form, for some reason unknown at the time, it was found to hasten maturity. On this discovery was based, and is still based, the chemical fertilizer industry, which in seventy years has grown to enormous proportions all over the world.

Insoluble Phosphates of Little Value

Professor Chester, of the Delaware Agricultural College, states* that an average of forty-nine analyses of soils shows enough *potential* phosphoric acid to produce fourteen bushels of wheat per acre per year for five hundred years. The question then arises, "Should the commercial farmer, who is dependent upon quick crops for quick returns, apply unavailable fertilizers, and especially insoluble phosphates, which neither supply the needed available phosphoric acid nor have any catalytic influence in the soil? In a word, shall he in this latitude, where the growing season is limited practically to 120 days, and where there is often a short supply of water, apply insoluble and unavailable plant food, while the soluble and available can be obtained at a relatively small cost over the insoluble?"

Ground Phosphates or "Floats"

Ground mineral phosphates, sometimes called "floats," are being recommended as absorbents under cattle and horses. They are, no doubt, a good absorbent, but no better than fine, dry earth. It is contended that in the manure pile, by the action of decomposition and nitrification of the manure, a certain part of the phosphoric acid will be rendered available, but how much will be rendered available is unknown. No prudent commercial farmer will depend upon it as a source of available phosphoric acid for hoed crops. He might as well depend entirely on hay for milch cows.

*See also page 27.

It is also urged that ground mineral phosphates, undissolved, should be applied directly to the soil. But why add more insoluble phosphoric acid when there is already in the soil a supply for many centuries? The phosphoric acid which is taken off in crops should be returned, but in a *soluble*, *diffusible* form, not only to feed the growing crop, but by its catalytic action to help in the diffusion and assimilation of other plant foods and so hasten maturity, for time is everything in this latitude.

Soluble and Diffusible

Basic Slag Phosphates

These are, no doubt, valuable in their place, but they have their limitations. According to the official methods of analysis in this country, slag phosphates contain *no soluble* phosphoric acid. Therefore, when one applies them, he is only adding to the sum total of phosphoric acid in the soil, of which the soil, as we have seen, contains enough for centuries. Slag phosphates, however, are made up of about one-fourth free lime, and are valuable where the soil is acid. Probably a considerable part, if not all, of the efficiency of slag phosphates is due *more* to the free lime than to the phosphoric acid which they contain. If one needs to use lime to sweeten his soil (and he frequently does) and at the same time desires to apply additional phosphoric acid in an inexpensive form, we recommend a mixture of 1,500 pounds of high grade superphosphate and 500 pounds of agricultural lime. This will give a ton which will contain as much active lime and practically as much phosphoric acid as slags contain, and will *cost less per ton* than slags. It will also have the advantage that the phosphoric acid will all be quickly available and since available phosphoric acid (soluble and reverted) is absolutely essential in the growth of quick crops, the application of acid phosphate and lime, applied separately or combined in a mixture as suggested, will be found far more efficient than basic slag phosphates, *as well as less expensive.*

Value Chiefly Due to Lime

A New Mixture

Potash, the Third Element

Viewed from the standpoint of their chemical analyses, potash (K_2O) plays an important part in the structure of plants. It is absolutely essential in the formation of the woody fibre of the stalk and in the sugar and starch contained therein, and especially in tubers and roots like potatoes and beets.

What Potash Does

It is never found in nature pure, but invariably in combination with some acid. One of its best known combinations is with carbonic acid, forming carbonate of potash, which is the common form in which we find it in ashes. It is the carbonate of potash which is leached out of ashes and which is used in the manufacture of soap. The exact form in which the potash exists in plants is not well understood, but it, in connection with silicic acid, is believed to aid in giving the stiff quality to the stalk and also to the hull of the seed. When a plant is burned, we always find potash in the ashes in the form of carbonate.

Nitrate of Potash

We also find it in nature in combination with nitric acid, forming nitrate of potash—a chemical which enters largely into the manufacture of gunpowder and is also used extensively in brines for pickling meats. This form of potash can be leached out of certain soils in which there is a large amount of organic matter or out of horse manure. It also appears in nature in the form of chloride of potash, which in chemical composition is a salt similar to chloride of soda (common salt).

Sources of Potash

The original and chief agricultural source of potash was the ashes from burned wood, and in this form it exists largely as carbonate and silicate of potash; but ashes afforded only a small supply of potash, and it became necessary to find some natural supply. This was found in Germany, so that today the world turns to that country for its source of artificial potash. The sources of potash, then, are the German potash salts, nitrate of potash, and, finally, wood ashes, chiefly from Canada.

Lime, Occasionally Needed

Sour Soils

Lime has been used as a fertilizer from time immemorial, but in later years it has been neglected because it has been overshadowed by the great trio, nitrogen, phosphoric acid and potash, and because it has been assumed that most soils contain enough available lime, which is no doubt true. Lime is an important ingredient of all plant structures, and of this, most soils have an abundant available supply. We have learned, however, that while soils do contain an abundant supply in available form, yet that it is necessary to apply it occasionally in a caustic form to correct "sour" soils.

Lime exists in nature as lime rock, which is carbonic acid and calcium combined, and is practically insoluble in water. Burning it drives off the water of crystallization, breaks down its structure, and leaves it in what is known as a caustic condition—that is, in a condition to combine easily and quickly with all acids, particularly with the weak organic acids of the soil,—and it is in this form that lime is of very great assistance in neutralizing the excess of soil acids and leaving the soil in a neutral or slightly alkaline condition. It is known that farm crops thrive best on a soil which is slightly alkaline, alkalinity being necessary for the growth of the nitrifying bacteria which must exist and thrive in all soils that support the higher orders of vegetation, such as farm crops.

How Lime Assists Crop Growth

Burnt lime is also exceedingly valuable on soils which have been over-manured, or on muck soils,—that is, soils which are rich in organic matter (humus)—in order to assist in breaking them down and rendering the plant food available, and also to aid in the formation of silicates of lime, which are necessary for stiffness or stamina in the stalk. Unfortunately, burnt lime (quicklime) cannot be introduced into mixed commercial manures, because it will set up a chemical action that causes the nitrogen which is present in the form of meat, blood and tankage, to be set free as ammonia, which passes off into the atmosphere as a gas, to the great detriment of the fertilizer.

How Much To Use

Therefore lime must be supplied to the soil in its clear state. Usually an application of about a ton to the acre once in two or three years will correct the acidity of the soil. This is an important thing to accomplish, as we shall see when we consider on another page the soil bacteria, or "yeast" of the soil.

The "Bulk" in Fertilizers

Consumers often wonder what is the "bulk" of a ton of fertilizer over and above the percentage of plant food. Thus, in a ton of high-grade fertilizer, only 400 lbs. of actual plant food is supplied. For example:

4 per cent of Ammonia	equal to		80 lbs. in a ton
10 " " " Phosphoric Acid	" "		200 " " "
6 " " " Potash	" "		120 " " "
			400 lbs.
Balance or "bulk" of the ton			1,600 "
		Total	2,000 lbs.

What is this 1,600 lbs. composed of? A part of it is really plant food, but not in the sense that the ammonia, phosphoric acid and potash are plant foods. It is plant food, chiefly humus, that is not charged for in the price. We will not go into a scientific analysis of this material, but every pound of it can be properly accounted for without the addition of any "filler" or make-weight. A cord of stable manure weighs about 4,000 lbs., but it contains not over 50 lbs. of actual plant food. What is the "bulk" or "filler" of manure?

The Bulk in Manure

Pure nitrogen, as we have seen, is a colorless gas, and in that condition it cannot be used as food for either plants or animals. Potash and phosphoric acid do not exist in an uncombined pure state in nature, and even if they did, such strong and caustic elements would be dangerous to handle and absolutely unfit for the tender rootlets to feed upon; so we obtain or combine them in forms suitable for agricultural uses.

Plant Foods Always Exist in Combinations

The active content of meat is protein, but the stomach could not digest protein in its pure state. We take it in beefsteak, which is 85% water and fibre. Milk consists of from 11 to 15% solids, composed of fats, sugar and cheese materials; the balance is water, but we cannot extract the water and use only the solids. The bulk of an apple, after the essential juice or cider is extracted, is pomace, or fibre, which possesses little or no value as food, but makes the "bulk" of the apple. Certain other things hold or carry plant food and constitute the

"bulk" of most fertilizers. The most concentrated forms of plant food are the following:

100 lbs. of Sulphate of Ammonia contain 25 lbs. of Ammonia and 75 lbs. of Sulphuric Acid.

100 lbs. of Nitrate of Soda contain Nitrogen equal to 20 lbs. of Ammonia and 80 lbs. of Soda, water and some impurities.

100 lbs. of Commercial Muriate of Potash (80% strength) contain 50 lbs. of Potash and 50 lbs. of Muriatic Acid, water and some slight impurities.

100 lbs. of the highest grade of Mineral Phosphates contain 40 lbs. Phosphoric Acid (P_2O_5), and the balance, 60 lbs., is lime, water and some slight impurities.

100 lbs. Dried Blood contains 15 lbs. of Ammonia; the remainder, 85 lbs., is organic matter or meat fibre.

No Make Weight Added

Anyone who has made "home-mixed" fertilizers from prepared materials like acid phosphate, dried blood, tankage, nitrate of soda, etc., knows what "bulk" is, and knows also that these materials, when mixed together, give a color which resembles earth, but he knows that no earth was added, and further that there was no room to add it without increasing the weight to more than 2,000 lbs. and correspondingly reducing the grade.

"Dryers" or "Conditioners"

We have tried to show in the preceding paragraphs what is the "bulk" in fertilizers and that dryers are rarely used. Occasionally, however, dryers are necessary in order to make the goods "dry and drillable". The scarcity of labor on farms, and especially its poor quality, has increased the use of farm machinery. Machines which apply fertilizers require that the goods shall be in a granular condition. Farmers who do not use machines also require that their fertilizers shall come to them in a mealy, uncaked condition. They have no time to stop to pound up lumpy goods in the spring of the year, when farm work presses; hence they demand perfect mechanical condition.

Fertilizers Must Drill Well

The chemicals which are used in mixed fertilizers, as we have seen, are concentrated forms of plant food. Like common salt, they have a tendency to absorb moisture in moist weather and to cake up in dry weather. Therefore, to make fertilizers dry and drillable, it is often necessary to use a dryer that will keep the materials, especially the chemicals, apart and from caking, as cornstarch is sometimes added to table salt to keep

it from caking. Understand, these dryers do not reduce the amount of the plant food guaranteed in a ton, for that is a known, fixed quantity which the manufacturer must state, guarantee and supply, or be liable to prosecution. These dryers rarely make up bulk, for they usually contain plant food themselves, such as phosphate and carbonate of lime. Some of the best known dryers are the "soft guanos" which come from the islands in the southern seas.

The Work of the Manufacturer

As manufacturers of fertilizers are expected to gather and make available all sorts and conditions of materials which contain plant food, in the interest of economic agriculture, they cannot pick and choose, but must utilize everything; hence "all things are fish which come to their net." To assemble them, to prepare them, and to put them in available form and perfect mechanical condition for easy distribution and quick field results, is the work of the manufacturer. It is no small work, and it requires well-equipped plants, comprising powerful mills as well as complicated chemical apparatus.

Farmers' Stock Rations

The prudent manufacturer endeavors so to balance his materials that no dryers are necessary, for everything which goes into a mixture, if it does not carry its share of nitrogen or potash or phosphoric acid, is just so much additional material to provide for and prepare; hence dryers are not used from choice, but only from necessity. A farmer does not feed all hay or all grain from choice, but a proper proportion of each; and if he is out of corn meal and shorts to mix with his gluten meal, which is very concentrated, he feeds a larger amount of hay. The result is practically the same, provided he supplies the same required amount of *digestible* food.

How to Secure Value in Fertilizers

"To state what one sells and to sell what one states" should be the underlying principle of all business transactions. As the fertilizer industry and all the fertilizer inspection laws are now based on this principle, the farmer can feel reasonably sure of getting what he buys as to the *quantity* of plant food in a ton of fertilizer. Unfortunately, official inspection, which is rigidly enforced in every state, while it reveals the quantity of plant food in a ton, does not and cannot, in the present state of chemical knowledge, reveal the *quality*, that is, the degree of *availability*. For the quality the buyer must still rely upon the integrity of the firm with whom he deals. Touching this point, the remarks

of the late Professor Johnson of Connecticut, the pioneer official fertilizer inspector, hold good. Referring to quality, he said:

> "The only security of purchasers of fertilizers is in dealing with firms which have the highest reputation*** and in avoiding 'cheap goods' offered by irresponsible parties."

Contract of Seller

The manufacturer is called upon to state and guarantee a given amount of plant food in each ton, in certain forms, and when he has done that, whether the goods are high grade and sell for $40 per ton, or low grade and sell for $20 per ton, he has performed his part of the contract. If he is a wise and progressive manufacturer, he will go further and make it a point to furnish the required plant food in *soluble*, *active* forms, properly balanced for the crops to be grown and in perfect mechanical condition, *and which will continue so until used.*

The Farmers' Guaranty

Some day the farmer, like the fertilizer manufacturer, will sell many of his products on a guaranteed basis and should receive credit and pay accordingly. For example: if he produces a rich milk which he guarantees to contain 15% solids with 5% fat, he should receive a higher price than for a grade which contains only 12% solids with 3% fat. Both grades may be absolutely pure milk, but the first grade is worth 25% more than the second grade as an article of food, and costs more to produce.

Chemically Mixed Fertilizers

vs.

"Dry Mixed" and "Home Mixed"

Many people have the idea that the mixing of fertilizers is a simple process; that a laborer with a shovel and a screen can do it; and so he can. But should we be satisfied with that sort of goods? The actual putting of the ingredients together is but the last step in a long process. Before they are mixed, the materials must be assembled, all of them ground and screened, and most of them should be chemically treated; many of them, also, should be thoroughly rendered of their grease, for grease is bad in a fertilizer for two reasons: it furnishes no plant food, and it causes the goods to be sticky, undrillable, and oftentimes to burn.

Chemical Blending

All these steps require a complicated chemical plant for this preliminary work without which no "home mixing" or "dry mixing" would be possible. A cook can take flour, butter, sugar and eggs, and make cake, but somebody has had to make in advance the flour, sugar and butter; and the baking process must follow the mixing process.

The chemical process of mixing fertilizers is one in which practically all of the materials except the chemical salts are subjected to chemical treatment in large revolving mixers, the contents of which are discharged into dens holding from 100 to 400 tons, and there allowed to mingle and compost in the presence of a high degree of heat, which has been generated by the splitting up and recombination of the chemical elements in the materials used.

What It Does

In this complex chemical process, the insoluble phosphate of lime in bone or mineral phosphates is rendered water-soluble and available, and at the same time the organic materials, such as tankage, fish, etc., will have been converted, a part into chemical nitrogen, and the remainder into an available form.

"Dry mixed" or shovel-mixed goods are those which are prepared by mixing the crude ingredients together—for example, the mixing of ground bone, ground phosphate rock or dry acid phosphate with tankages, etc. Such a mixture is purely a mechanical union in which no chemical action takes place. We can make a dry mixture of lime and sand, but the moment we add water, chemical action sets in and we have mortar, which is quite another material. Flour and water and a little salt could be mixed up and served as food, but it would not be bread. It is simply dough, not cooked bread which is palatable and digestible. Chemically made fertilizers, like properly made bread, are the prepared food or bread of plants, and are as superior to "dry mixed" or shovel-mixed fertilizers as bread is superior to the crude grains from which it is made. Now the chemical process of making fertilizers is the outcome of long experience in the chemical fertilizer industry, which seeks to render, and actually does render, practically all the plant food available for plants, as the cooking of meats and vegetables renders them available for man.

Mechanical Not a Chemical Union

Processes vary in treating by-products which contain plant food. In some cases the processes are so conducted as to take out all the grease and leave the by-products in a hard, unavailable condition. In other cases they are so conducted that, while most of the grease is extracted, the product is left in a soft, available condition. It depends largely upon the apparatus used and the temperature employed. Everyone knows that beefsteak can be cooked in a way that will leave it very indigestible, or it can be served tender and juicy and easily digestible.

Difference in Processes

There are forms of nitrogen in the market which are more or less inert, including many so-called tankages or bloods, which are dried and ground, either separately or mixed with good tankage or dried blood, and sold to dry mixers or home mixers as tankages, much as a little cream used to be mixed with oleomargarine to give it the aroma and taste of butter. These, if only "dry mixed," while giving goods that may show up well in the laboratory, do not show up well in the field, for they have not been properly cooked, as it were; and after all, it is the field test which tells the story. The practical farmer who is growing quick crops for quick returns wants goods that will act during

Good and Poor Forms of Nitrogen

the current season. He considers the following season when he gets to it.

Therefore, in deciding between chemically prepared goods and "dry mixed" or "home-mixed" goods, there are two points to be considered:

Why Fertilizers Are Bought

First: Fertilizers are purchased and used, not for their crude plant food, but for their available plant food. They are bought to supplement the crude manure on the farm, to start crops as well as to carry them through to maturity, to produce results in dry seasons as well as in wet seasons. Will "dry mixed" or shovel-mixed goods which have not been subjected to chemical treatment give the same results as chemically mixed goods? Will they be as soluble, as active *and as sure?*

Second: Will "dry mixed" or shovel-mixed goods be as thoroughly mixed and blended as chemically prepared goods? Will each pound of soil get its half-grain or grain of fertilizer? It must be remembered that when we apply as large a quantity as a ton to the acre of concentrated fertilizer, we are giving each pound of soil less than a grain of plant food. For this infinitesimal quantity to be thoroughly and evenly distributed, the goods must be dry and drillable as well as soluble and available. Finally, we must remember that in this latitude the growing season for most crops is limited to 120 days. Will crudely mixed fertilizers *insure* crops to the same extent that chemically prepared goods will insure them? Judging by the enormous increase in the consumption of chemically mixed fertilizers, the practical farmer has decided in the negative.

The Availability of Fertilizers

Availability and Mechanical Condition

It must be borne in mind that commercial manures are applied chiefly to hoed crops, many of which have small root systems, mature in from sixty to one hundred and twenty days, and are often put to it to find sufficient moisture. Theoretically and practically the commercial farmer, for best results, wants every seed to germinate, every plant to mature, and hence every pound of the soil to be enriched with its fraction of a grain of available plant food. Therefore *availability*, *diffusibility* and *fine*, *dry condition* for even distribution are of paramount importance to the man who is growing quick crops for quick returns in this latitude. Will "home-mixed" or "dry

mixed" goods, which any farm laborer with a spade can prepare, *insure* him the same results as chemically prepared or predigested goods? A stunted crop, like a stunted calf, rarely amounts to anything.

Balanced and Specialized Fertilizers

Well-balanced, specialized fertilizers, containing the right amounts of *available* nitrogen, in both chemical and organic forms, with an excess of soluble and reverted phosphoric acid, both for fertilizing and catalyzing effects, and the proper amount and right form of potash, all thoroughly blended together and in forms that will not cake, but remain in a drillable condition, and which will act not only in the beginning, but throughout the season (fertilizers based upon the needs of the crop and market requirements), are what the practical farmer should rely upon in growing commercial crops. Above all things, he should avoid unbalanced and improper mixtures that have the defect of one element being *insoluble* and another element *too* soluble for successful plant growth.

What to Avoid

Professor Voorhees, of New Jersey, an authority on the subject, recommends applying an abundance of a well-balanced, available fertilizer, as much as 1,500 or 2,000 pounds to certain hoed crops where no manure or "cover crop" is plowed in. The late Professor Stockbridge emphasized the importance of adapting the fertilizer to the crop, and especially that the fertilizer used should contain the dominant element which that crop required. The expert potato growers of Maine, the market gardeners of Long Island and New Jersey, all follow this practice and are making money.

The sanest, shrewdest farmers apply ample dressings of well-made, specialized, available fertilizers to *insure* profitable crop growth, for, after all, it is *crop insurance* that the practical farmer is after. He takes long chances with the weather, but he takes no chances with the kind of fertilizer he applies, for he knows that an extra dollar expended for the right kind will make just the difference between success and failure.

Crop Insurance

The "Yeast of the Soil"

or Soil Bacteria

How One Order of Life Helps Another

"The yeast of the soil," as we shall consider it, is not plant food, but low organisms of life which exist in the soil and but for which cultivated soils would be practically barren. "The yeast of the soil" is what is scientifically known as bacteria—organisms which thrive in the soil and by means of which unavailable plant food, especially nitrogen in the form of organic matter, such as stable manure (leaves, stalks, etc.), is rendered available. The great discoveries of Hellreigel, the leading investigator along this line, demonstrate that higher orders of plant life are dependent upon lower orders of life. We could not profitably grow a corn or potato crop unless these organisms were growing at the same time in the soil, or had previously existed there and done their work.

Why a Soil Is Cold

We speak of a soil as being cold and non-productive. It may be cold from an excess of water, or because it is too compact and heavy, but the moment we drain it or lighten it by cultivation, it becomes productive. The real reason it becomes productive is that we admit air and warmth, which are necessary to develop the crop and also the "yeast plants" (bacteria), which, in turn, attack the stable manure or other organic matter (humus), and break it down, rendering it available to plants. Farmers say that they can hear corn grow on warm days and hot nights, which is almost literally true. It is because the weather is favorable to the growth of the nitrifying plants (bacteria of the soil), which convert the unavailable nitrogen into available and soluble forms.

How Yeast Works

It is a well-known fact that the yeast used in making bread and the "mother" used in making vinegar are nothing but an aggregation of bacteria, "yeast plants," as it were. When the yeast is added to bread under warm, favorable conditions, it begins to grow, and in its growth liberates carbonic acid gas, which causes the bread to rise and become light and porous. In the case of vinegar a ferment, or "yeast plant," attacks the sugar of the cider and converts it into alcohol; then the "mother" of

vinegar (another kind of bacteria) attacks the alcohol and converts it into an acid which we call vinegar.

Similar forms of life are at work, under warm, favorable conditions, in the soil, preparing plant food for assimilation. Not only are warmth and the right proportion of moisture necessary for their growth, but the soil must be neutral or slightly alkaline for their highest development. In order to produce this condition, an application of quicklime or unleached wood ashes is frequently necessary to correct any acidity of the soil resulting from organic acids which are produced under certain soil conditions.

Lime Helps

All organic matter or substances which have been at some time organized into plants by the life force, such as leaves, roots, stems, etc., must decay before they can nourish, that is, before they can be absorbed and reorganized again into growing crops. Stable manure contains a small amount of soluble salts which are immediately ready to feed the crop, but the bulk of the manure must rot down through the influence of bacterial action before it becomes food; and the process of decay, or rot, is largely the result of the growth of lower forms of life, or "yeast plants," in the manure or in the soil, which, as we have seen, are dependent upon certain favorable conditions.

Decaying Organic Matter

There are several known forms of nitrogen organisms in the soil, two that are well defined, the de-nitrifying and the nitrifying—the destructive and the constructive. Touching the various organisms, Professor Stone, of the Massachusetts Agricultural College, writes:

"The de-nitrifying organisms are those which convert nitrates into *nitrites* and *ammonia.* The nitrifying organisms are those which convert ammonia into *nitrites* and *nitrates.* The latter are exceedingly beneficial, while the former are not considered so, as plant food must be in the form of *nitrates.* We never find *nitrites* in plants. There is another type of organism known as nitrogen fixation organisms, and which are represented by the organisms in legume nodules; also by many free organisms which exist in the soil. We do not know much about these organisms, but we do know that there are quite a number of them. Some of them appear to work better when living with other organisms than when isolated by themselves. There is evidence to show that a large number of organisms have the power of fixing nitrogen in the soil; for example, besides the species of clover bacteria, there is evidence to show that many of the algae which live in the soil and certain molds will do the same thing. In our work here, we find the largest percentage of nitrogen in those solutions which are contaminated with the blue bread mold

Nitrifying and De-nitrifying Organisms

(Pencillum), showing that it is a nitrogen-fixer. I think it will be shown later on that quite a little nitrogen is fixed in the soil by this type of organism, exclusive of those on the nodules of the legumes. The denitrifying organisms are often found in manure piles and are responsible for the liberation of ammonia and, as such, we would not consider them favorable."

Forcing Early Growth

In the spring of the year, when the weather conditions are usually unfavorable for the propagation and rapid multiplication of these soil "yeast plants," commercial manures are found of great assistance in forcing an early growth by supplying forms of plant food which have been rendered soluble by chemical treatment or are, so to speak, predigested, and ready for the crop to feed upon immediately. Since most of our cultivated crops make their chief growth in from sixty to ninety days, it will be clear that we must have plant food in the soil that will feed the plant from beginning to end, especially in the beginning of the season, when the bacteria of the soil, owing to weather conditions, are not active.

The Modern Explanation of Composting, Drainage and Cultivation

The discovery of soil bacteria, which also exist in stable manure, explains the advantage of composting and cultivation for forcing early growth. In the majority of cases, it is no doubt cheaper, if not better, to apply stable manure in its crude state directly to the soil, to cultivate it into the soil and allow the bacteria to attack it there; in short, to compost it in the soil rather than beforehand. In many cases it is desirable to use some thoroughly composted stable manure—manure which has been subjected to the bacterial process, broken down, and a considerable part of its crude plant food converted into available forms. This, however, was deemed more necessary years ago, before commercial manures were introduced. Now that concentrated available plant food can be bought, the necessity of composting manure in advance is passing out. It is not only a slow process, but more or less wasteful and expensive, for in the process of nitrification through the bacterial action a considerable amount of ammonia may be set free and wasted into the atmosphere. This always takes place when the manure or compost pile is allowed to "fire fang" and turn white.

Compost Passing Out

It is urged, however, by some experimenters that composting is desirable in order to raise the temperature of the manure pile to a point that will destroy the foul weed seeds, but is not this an expensive way to destroy weed seeds, as obviously it must expose the compost to loss of ammonia while also consuming time and labor? Except where a very fine seed bed is desired, with considerable humus present, it is believed the compost heap will go out and commercial manures will be used in its place for forcing purposes.

Object of Drainage

In the matter of drainage, the old theory obtained that we wanted to draw off the water from the soil in order to admit air and warmth, and also afford a better chance for the roots to permeate through the soil. This is all true today, but we have found that this is only a small part of the advantage of drainage. The paramount object of drainage is to promote the growth of bacteria in the soil—a life which cannot exist where there is an excess of water, where the soil is too compact, or where the proper amount of air and warmth does not permeate. Hence drainage assists in the growth of a crop of "yeast plants" below the surface of the soil, which are as essential to the growth of the crop above the soil as water and sunshine.

Object of Cultivation

In the matter of fine cultivation, the *old theory* of cultivation was to kill not only the weeds, but to make the soil light and friable, to admit the air, to encourage the circulation of moisture through the soil, and to make it an acceptable medium for the roots of the crop. The *modern theory* includes the old and also recognizes the necessity of making the conditions as favorable as possible for the growth of soil bacteria. Thorough cultivation also conserves the moisture of the soil by means of a fine mulch on the surface, which prevents the moisture from evaporating into the atmosphere.

Horse Leg Irrigation

In the West, where they carry on "dry farming"—that is, farming without irrigation—where there is little rainfall—they have been successful in raising large crops by continuous cultivation, keeping the surface like a dust heap, thus retaining the moisture which, by means of capillary action, has been drawn up from lower levels. Mr. Hale, the celebrated peach grower of Connecticut, keeps horse cultivators going practically all the time in his orchards, during the growing season, not only to keep down weeds, but to conserve moisture. He calls it "horse leg irrigation." Thus the modern farmer

cultivates not solely to kill weeds and admit warmth and air into the soil, but to encourage the growth of bacteria, as well as the distribution and conservation of soil moisture.

"The Sap of the Soil"

We frequently hear farmers speak of the "sap of the soil"—a phrase which expresses a great deal. All cultivated plants take up their food in dilute solution. The sap of a tree or plant circulates throughout its system of trunk, branches and leaves, carrying with it the nourishment necessary for its upbuilding, as does the blood in animals. This sap has been absorbed from the soil through the roots of the plant, and is charged more or less with plant food ingredients which were either applied in a soluble form or were rendered soluble through bacterial action in the soil, or through the digestive process which takes place in contact with the roots of plants. Manure or commercial fertilizers enrich the sap of the soil by supplying additional quantities of available plant food. Bacteria, as we have seen, help to break down the organic forms of plant food and render them soluble for the sap of the soil to absorb.

Potential Fertility

Chemistry teaches us that plants are composed of certain fixed elements which are supplied by the soil and the air. It further teaches that while there is an abundant supply, yet we have exhausted the three leading elements, nitrogen, phosphoric acid and potash in available forms; that so-called barren or unproductive soils may be rich in plant food elements, but that these elements are so locked up as to be of little value to the commercial farmer, whose chief concern is quick crops for quick returns. In other words the available plant food (nitrogen, phosphoric acid and potash) has been exhausted, leaving only the unavailable or what is known as the potential fertility, which, by the slow processes of nature, is yielded up too slowly to be depended upon by the commercial farmer.

Plant Food Locked Up

It has been known for a long time that practically all tillable soils are rich in all plant food elements, and yet many of them are barren and most of them will not produce profit-

able crops without the aid of manure or fertilizer. Prof. Frederick D. Chester, of the Delaware Agricultural College, states:

Amount of Plant Food in Soil

> "An average of the results of 49 analyses of the typical soils of the United States showed per acre for the first eight inches of surface, 2,600 lbs. of nitrogen, 4,800 lbs. of phosphoric acid and 13,400 lbs. of potash. The average yield of wheat in the United States is 14 bushels per acre. Such a crop will remove 29.7 lbs. of nitrogen, 9.5 lbs. of phosphoric acid and 13.7 lbs. of potash.
>
> "Now, if all the potential nitrogen, phosphoric acid and potash could be rendered available, there is present in such an average soil, in the first eight inches, enough nitrogen to last 90 years, enough phosphoric acid for 500 years and enough potash for 1000 years.
>
> "This is what is meant by potential soil fertility, and yet such a soil possessing this same high potential fertility may, under certain conditions, be so actually barren of results to the farmer as to lead him to believe it absolutely devoid of plant food."

In a word, potential fertility represents plant food which is so tightly locked up that it is not available for present needs, and becomes available only through the process of decay and disintegration, which is too uncertain to meet the requirements of modern, intensive farming.

"The Little Balance"

Fertilize for Maximum Yield

Therefore, in modern practice, instead of asking the soil how much of the potential fertility can be depended upon for each crop, or what the "natural yield will be" (a question which will never be satisfactorily answered), we now apply what we believe to be necessary to produce the maximum yield over and above the natural yield of the land. In all cases we find that the actual requirements of plant food for various crops are very small indeed, in many cases less than a grain of available plant food to each pound of soil — so little to produce so much, and yet if it is absent, the crop will be a failure. It is this little, essential balance of available plant food which stands between success and failure and which concerns the modern farmer today.

Stable Manure
and
Commercial Fertilizers

Weight and Composition of Manure

It is estimated that a cord of stable manure, weighing 4,000 lbs., contains, on the average, 50 lbs. of plant food, worth about $3, the remainder (3,950 lbs.) being water, straw and organic matter. For the 50 lbs. of plant food to be rendered available, we are dependent very largely upon bacterial action in the manure and in the soil. In the old days, with cheap labor, we composted manure in advance in order to hasten the process of decomposition and increase its availability. Now, as a rule, depending upon commercial manures for active available plant food, we apply the manure on the soil directly as we produce it or receive it from city stables.

Its Chief Value Comes from Humus

While there are only 50 lbs. of actual plant food (nitrogen, phosphoric acid and potash) in a cord of manure, yet we must not overlook the value of the organic matter, straw, etc., not only for the humus which is added to the soil by means of the manure, but also for the improved physical condition which it imparts to the soil. This humus no commercial manure supplies, and in this respect stable manure is superior to commercial manures; but the value of this excessive amount of humus in stable manure, as a source of plant food, depends, as we have seen, not only upon a thorough distribution of the manure in the soil, but chiefly on normal conditions of warmth and moisture, in order that bacterial action may be induced and by means of which it is rendered available. Thus, when we rely solely on stable manure, we are more dependent on weather conditions than when we apply predigested fertilizers, or part fertilizer and part manure.

Best When Used with Fertilizers

Stable manure, as a by-product of the farm, will be a favorite source of fertility, partly because of its plant food and chiefly because of the humus it supplies, but in market gardening and in general farm practice the best results will be obtained when it is used in connection with chemical manures. On the other hand, chemical manures not only supply in a concentrated way needed plant food, but supply it in forms that *anticipate*,

supplement and in some cases *promote* bacterial action, without which stable manure, and even the organic portion of the fertilizer, would be barren in results. The progressive farmer, therefore, supplements and improves his stable manure by the use of concentrated fertilizers in the same way that he supplements and improves his hay with the use of concentrated grain foods in feeding his stock.

Manure Not Cheapest Source

While it is absolutely true that stable manure is a good source of fertility, yet it is by no means the cheapest if one has to buy it, neither is it absolutely essential in the growing of many farm crops. This is shown by the enormous and rapidly increasing areas which are planted annually to corn, cotton, tobacco, wheat, potatoes and vegetables on commercial fertilizers as the sole dependence in the matter of plant food. In fact, the best potatoes and vegetables are now grown on commercial fertilizers as a rule.

Incidentally, it should be noted that twenty years ago manure sold in city stables at about $10 a cord. Today, unless a stable is very advantageously located, farmers and gardeners are getting manure at a nominal price, and, in many cases, for the hauling. The introduction of commercial manures has been one of the causes of the reduction in the price of stable manure, for which the farmers should be thankful.

Manure-Sick Land

The Germans have a phrase which signifies "manure sick land." With cheap stable manure we are likely to have such a condition around large cities. On such land commercial manures should be applied, and occasionally lime or wood ashes, in order to promote the slightly alkaline condition of the soil which is necessary for satisfactory crop growth.

Count the Cost before Buying Manure

Finally, the question as between the purchase of stable manure and commercial fertilizers resolves itself into two parts: *First:* Do one's soil and the character of the crops to be grown require the excessive humus of stable manure for the most profitable returns? *Second:* How much can one afford to pay for this humus, knowing that it can often be obtained, or all that is needed, by a rotation of crops or by plowing in stubble or green crops? Assuming that the actual plant food in a cord of stable manure is worth, on a fertilizer basis, $3 per cord, what is the humus, the remainder of the cord, worth, and how much will it cost to haul or freight it and apply it to one's own soil and crop requirements?

Intensive Farming

Abnormal Crops Require Special Feeding

Progressive farmers and market gardeners are carrying on "intensive agriculture." They produce abnormal crops and therefore require intensive methods of cultivation and feeding. A potato plant left to itself and in the state of nature produces potato balls. Man, by modern methods of cultivation and selection of seed, has changed the nature of the plant to produce tubers. A cabbage left to itself would run to a seed stalk, but we cultivate it for its head alone, which is an aggregation of leaves that are very palatable as a food for man, but quite exhaustive of the soil. As we have changed the nature of most of our cultivated crops, so we must change our methods of cultivation and especially our methods of feeding them. The old method of relying wholly on stable manure, raw or composted—waiting on the slow processes of nature to render it available—must give way to quicker and surer methods for the commercial farmer and gardener of today.

What They Are Doing in Europe

Barren Heath Made Fruitful

"About the middle of the last century a lighthouse, known as Dunston Pillar, was built on Lincoln Heath, in Lincolnshire, England. It was erected to guide travelers over a trackless, barren waste, a very desert, almost in the heart of England, and long it served its useful purpose. The pillar, no longer a lighthouse, now stands in the midst of a rich and fertile farming region, where all the land is in high cultivation. For many years, no barren heath has been visible even from its top." Such is the story told by the veteran agricultural chemist, the late Professor Johnson, of Connecticut, to which the late Professor Atwater adds: "Had not chemists busied themselves to find out what makes plants grow, and had practical farmers not been ready to use their discoveries, Lincoln Heath would still remain a waste. What is true of this bit of English soil is true in greater or less degree of wide areas of our own and other lands."

Prince Kropotkin of France, a Russian exile, in an article on "The Coming Reign of Plenty," writes:

"If we want, however, to know, what agriculture can be and what can be grown on a given amount of soil, we must apply for information to the market-gardening culture in the neighborhoods of Paris, Amiens and other large cities in France and in Holland. There we shall learn that each hundred acres, under proper cultivation, yield food, not for forty human beings, as they do on our best farms, but for 200 and 300 persons; not for 60 milch cows, as they do in the Island of Jersey, but for 200 cows and more if necessary. They (the gardeners) have created a totally new agriculture. They smile when we boast about the rotation system having permitted us to take from the field one crop every year, or four crops every three years, because their ambition is to have six and nine crops from the very same plot of land during the twelve months. They do not understand our talk about good and bad soils, because they make the soils themselves. They aim at cropping not five or six tons of grass on the acre, as we do, but fifty to one hundred tons of various vegetables on the same space; not $25 worth of hay, but $500 worth of vegetables of the plainest description, cabbage and carrots. That is where agriculture is going now."

Five Hundred Dollars per Acre

Prince Kropotkin adds: "In the hands of men, there are no unfertile soils. The most fertile soils are not in the prairies of America, nor in the Russian steppes; they are in the peat-bogs of Ireland, on the sand-downs of the northern seacoast, on the craggy mountains of the Rhine, where they have been made by man's hands."

A French scientist once longed for two degrees less of latitude, that, among other things, he could have the luxuries of the season. The market gardener in the neighborhood of Paris has practically eliminated the matter of climate. In fact, he defies climate. By his wall culture, glass houses, cold frames, etc., he has made a rich southern garden from which he supplies the city of Paris "with mountains of grapes and fruit in any season, and in spring he inundates and perfumes it with flowers"—in addition to an abundance of plain vegetables. In no city are the products of the garden and greenhouse cheaper or better.

Culture Defies Climate

What We Are Doing at Home

But we need not go to France or Holland to find intensive farming. Within a few miles of our largest cities we are, in a measure, duplicating the results about Paris—perhaps not so intensively, because market conditions do not require it, but certainly quite as scientifically and profitably. We have our intensive farmers who are not satisfied with a return of $100

per acre, but demand and actually receive $500, $1,000 and, if covered with glass, fully $10,000 net per acre. These progressive men, like the Paris gardener, also defy climate and soil.

We will not attempt to detail the steps which have led up to this satisfactory condition for both producer and consumer. Suffice it to say that it is due partly to intensive methods which have been worked out by practical, hard-headed men, and partly to scientific research. It is a splendid example of Science and Practice going hand in hand—of the selection and breeding of seeds and plants, of successfully combating plant diseases and insects, of conserving and distributing the needed moisture, and, finally, of utilizing all the sources and forces of fertility.

Plant Food Supply

Many New Sources

As manufacturers, studying ways and means of supplying the plant food which is required by intensive methods in some sections and by wasteful methods in other sections, we are often asked where it is all coming from, and if we can keep up with the demand Knowing what science has done and is capable of doing, we have no fear but that so far as plant food is concerned we shall find the needed supply. Just now our chief concern is for nitrogen and potash. Discoveries will render the nitrogen of the air available—in fact, discoveries which are claimed to be a commercial success have already been made. The bacteriologist, through his study of life of the soil, will also help us in this direction. We are now, through the efforts of the chemist, also utilizing numerous by-products of our industries which a few years ago were thrown away, while new and extensive discoveries of phosphoric acid, in the shape of mineral phosphates, are being made. It only remains now to find some native source of potash, like that in North Germany, or some feasible way of rendering avail able the potash in feldspar rocks. Then we shall have rounded out the circle in America.

New Discoveries

The Application of Fertilizers

Almost as much depends upon the proper use of fertilizers as upon their composition. We must remember that chemically prepared fertilizers are *prepared plant foods;* that for best results they should be applied to a properly prepared seed bed or field. To feed highly concentrated foods to an old, winded horse or a sickly cow exposed to the cold and wet, is usually money and labor thrown away; so it is money and labor poorly expended to buy commercial manures and apply them to sour, wet, half-baked land, or to land half plowed and poorly prepared.

Weeds Thrive on Fertilizers

Again, it is money poorly expended to apply chemical manures to land where poor seed is used, or where, after the crop has come up, it is neglected. Weeds, as well as cultivated crops, thrive on fertilizers. The only merit which weeds possess (if they possess any merit at all) is that they sometimes do for the farmer what he has neglected to do for himself. If he neglects to cultivate and protect the original crop which it is good for him and the soil to grow, provided it is properly grown, weeds step in and cover the ground, protecting it and, when plowed in, supply a certain amount of plant food and humus that is good for the soil.

Value of Weeds

Nature abhors a bare spot, so she sets to work to cover up bare spots with some sort of growth, even if it be only noxious weeds. In this sense they are a sort of catch or "cover" crop, occupying the land until a better crop takes their place. If there is any comfort in this view of the weed question, the shiftless farmer is welcome to it; but we do not recommend fertilizers to grow weeds even as catch or cover crops. Fertilizers are too costly for that purpose. Dirt is described as matter out of place; a weed is a growth which is out of place. Do not tolerate it anywhere, and certainly not on land which has been enriched with chemical manures for which one has paid good money. (See Note, p. 34.)

The Object of Cultivation

The modern farmer keeps the horse cultivator going almost constantly. He does not wait until the weeds have come up, but he nips them before or as soon as they have germinated, thus not only destroying the seed or the weed itself, but before it has got a footing, and long before it can go to seed to reproduce itself in the same field another year. In fact, the modern farmer cultivates not to destroy half-grown or full-grown weeds, but for the good of cultivation itself—to keep the surface of the soil in a fine, friable condition, to form a mulch on the surface which is known to conserve the moisture of the soil and thus to offset the effect of drouth; also to thoroughly mix the fertilizer or manure with the soil in order that each pound of soil may have its grain of plant food, and in order that the little rootlets may have an easier and better place in which to feed. Finally, he cultivates to admit the air and warmth in order to promote a crop of bacteria in the soil, without which the crop above the soil will not thrive.

Cultivation Enriches Soil

The modern farmer, therefore, cultivates *to enrich his soil*, for that is what he really does when he conserves moisture and encourages the growth of bacteria. The killing of weeds is only incidental. In fact, if he has been thorough in his previous treatment of the soil, he practically has no weeds to kill, for they have been cultivated to extinction, except in case of frequent applications of stable manure.

To thousands of practical farmers in the East, and to many "dry farmers" in the West, weeds and ordinary drouth are no terror, they do not enter into their calculations; but these advanced farmers cultivate, and cultivate, and still cultivate. Thus their crops thrive and they thrive with them.

Reduce Acreage and Intensify Treatment

Use High Grade Fertilizers

This leads us to recommend a reduction in the amount of land cultivated, and to apply the same quantity or even more fertilizer per acre to the reduced area. We also recommend that high-grade fertilizers be used, for in the end they are cheapest. The overhead or general expenses which must be

NOTE.—Since writing the above (page 33) about weeds, the author has heard, at a public meeting, a successful market gardener state that he favored a growth of weeds after the chief crop was matured or harvested, in order to catch and hold any soluble plant food which might be left over in the soil; the weeds to be plowed under in late fall or early spring.

added on to a ton that sells for \$30 or \$40 are no greater in amount than must be added on to a ton that sells for \$15. The cost of preparation, bags, freight, etc., is the same in each case.

It Pays

We make this recommendation not so much to increase our sales as to increase *your* profits. There are farmers who apply from 1,500 to 2,000 lbs. of high-grade fertilizer to an acre of potatoes—fertilizer that is twice or three times as rich as that used in some other sections of the country. As a result, coupled with thorough cultivation, they grow 300 bushels of potatoes to the acre. Is not the unit cost of a bushel of potatoes much less when 300 bushels are grown on *one* acre than when they are grown on *three* or *six* acres?

Reduce Unit Cost

Successful manufacturers seek to reduce unit cost, and to that end they seek by modern methods and machinery to increase the production of their factories. We believe it would pay farmers, in order to reduce the unit cost of a bushel of potatoes or a bushel of wheat, to cover less land and to cultivate it better, using not only more fertilizer per acre, but a higher quality. The average yield of wheat in the United States is 14 bushels per acre, and yet there are farmers getting 30 and 35 bushels per acre. The average yield of corn is less than 30 bushels per acre, and yet there are farmers in the East who, on what would be regarded in the West as barren land, by the application of 1,000 lbs. of high-grade fertilizer and good cultivation, are harvesting 75 and 100 bushels of shelled corn per acre. It is obvious that where we intensify the treatment, that is, enrich and cultivate better, we can materially reduce the labor cost as well as increase production.

General Directions

Broadcast: Where fertilizers are used liberally, say from 1,500 to 2,000 lbs. per acre, and *without stable manure*, a broadcast application is usually safest. It should not be plowed in or applied much in advance of seeding. It should be worked in with a wheel harrow or horse cultivator, and thoroughly mingled with the top surface of the soil. Unless one has a broadcast sower, it is well to apply one-half walking in one direction (north and south), and the remainder in the opposite direction (east and west). One who can sow a few bushels of grass seed over an acre can easily broadcast fertilizer.

How to Broadcast

Some farmers mix the fertilizer with a quantity of dry earth in order to increase the bulk. Still others mix it with several loads of fine stable manure and then put it through an ordinary manure spreader, the point being to get it applied as evenly and cheaply as possible.

Part broadcast and part in hill or drill: Where fertilizers are used extensively and exclusively, probably more is used part broadcast and the remainder in the hill or drill than in any other way. This method gives the crop something to feed upon at the start before it has developed an extensive root system. This custom is quite generally followed in the case of Indian corn, potatoes and some vegetables. Where part manure is applied and part fertilizer, the manure is rarely composted, but is spread broadcast as it comes from the yard, cellar or pit, and wheel-harrowed into the soil, while the fertilizer is applied in the hill or drill.

A Good Start Helps

Hill and drill application: The old way was to apply all the fertilizer in the hill or drill, and this is still a good way if it is being used on crops with small root systems such as the small grains and some root crops possess, but care should be exercised not to place it in contact with the seed or young roots. A good fertilizer will burn unless it is mixed with the soil, and if it did not burn, the expert user would condemn it with some reason.

Hill or Drill Application for Small Root Systems

The modern drills or planters are so fitted as to distribute

and cover fertilizer in advance of the seed. Where the machine does this thoroughly, it is one of the cheapest and best ways to apply fertilizer for many crops. Some farmers furrow their land and then sow the fertilizer along the furrows and kick earth over it where the seed is dropped. When it is applied directly in the hill, it should never be thrown in handfuls in one spot, but scattered over the ground where the hill is to be, and earth kicked over it before the seed is dropped. After a little practice one gets the knack of successfully applying fertilizer by hand or with machines.

Caution

Frequent applications: Where fertilizers are used in heavy doses and exclusively, farmers frequently apply a portion at seeding time and the remainder between the rows or drills as the crop is cultivated. This is particularly recommended for many hoed crops and especially on light soils with a tendency to leaching. "Feed the crop a little at a time and often" is not a bad motto, especially when it can be done without much extra cost for labor. This course is being followed in many sections when the crop is backward or when it needs to be forced in the middle of the season. More and more fertilizer is being used in this way.

Apply More Than Once

Where to Use Manure and Where to Use Fertilizers

As a rule, it will not pay to buy and haul manure to the farm, but what is produced on the farm as a by-product should be used about as follows:

First: As manure is bulky and heavy for the plant food which it contains (not over 50 lbs. in a cord, weighing not less than two tons), it is best to use it near the barn or on fields easily accessible, and fertilizers on fields which are some distance off or hard to reach. It is difficult to compare fertilizers and manure, but, generally speaking, one bag of good fertilizer contains more plant food than a big cartload of manure.

Don't Cart Manure Too Far

Second: As the bulk of manure is humus, organic matter (hay and straw), it is also good practice to use it in larger quantities on heavy soils which need lightening and warming up, and also on light, gravelly soils which need the humus of the manure to improve texture and to retain moisture. Ma-

Use Manure to Lighten Soil

nure used on such fields, and especially in connection with chemical fertilizers, will prove best in the long run.

Manure for Slow-Growing Crops

Third: As manure is slower in its action than chemically prepared fertilizers, it is usually better practice to use it in large quantities in seeding down land to grass or on crops which take the longest period to mature, and to use fertilizers on hoed crops, and especially on crops which mature in from 60 to 90 days, such as potatoes, vegetables and corn. In fact, the best potatoes are now grown on fertilizer alone, since they are more mealy and less scabby than when grown on manure.

Fertilizers for Quick-Growing Crops

Therefore, generally speaking, quick-growing, hoed crops should be planted on fertilizers, and grass on manure, using the manure for seeding down in much larger quantities than formerly. Fertilizers can be relied upon as the sole and cheapest source of plant food for all crops and on all soils. Remember that *a one-horse load of fertilizer* will fertilize from one to four acres that would require from twenty to forty *two-horse* loads of manure.

Best for Grains

Fertilizers are also good for all grain crops, especially wheat, sown broadcast or drilled in with the seed, to insure a good catch, stiffen the straw, increase the yield, and to give a plump, handsome kernel and strong, healthy roots which will stand the winter and the attacks of insects.

Specific Directions

It is difficult to give specific directions for the application of fertilizers, which will apply alike to all localities. In all cases the amount of fertilizer used is dependent on its strength, the character of the soil to which it is applied, and the amount of manure or other dressing used in connection with the fertilizer; also the character of the previous crop and the previous treatment of the soil, such as the plowing in of green crops, etc.

The method of application is also influenced by the nature of the crop. Crops, like corn or tobacco, with extensive root systems thrive best when a large part of the fertilizer is sowed broadcast or drilled in before planting, while crops with small root systems, such as small grains possess, do best when the fertilizer is applied in drills or furrows. We give below the usual practice in localities where fertilizers have been used longest and in largest quantities.

Consider Nature of the Crop

Potatoes

Aroostook Method: As the best potatoes are now grown invariably on fertilizers exclusively, and as the farmers in Maine are among the most successful growers in the country, we think it will be interesting to our patrons to give a brief account of potato growing in that State. The following statement is from a grower and one of the best observers in Maine:

> "*Preparation of Land:* We turn over the sod, usually clover, as soon after haying as is convenient, but if the clover is growing luxuriantly, we wait till about the time the frost would take it. In the spring the turned-over sod is harrowed until fine and mellow. Then, between the 10th and 20th of May, the potatoes are planted with a two-horse planter which opens the rows, distributes the fertilizer, mixes and covers it with dirt, and then drops and covers the seed, also marking the next row—all done at one operation. The rows are usually set thirty-six inches apart, as being the best distance for two-horse cultivation.

Potatoes Follow Clover

Close Planting for Table Size

"*Seeding:* The seed (consisting of small potatoes about the size of hen's eggs) is cut usually with two eyes to each piece and dropped from 10 to 14 inches apart in the furrows. The tendency is, however, to reduce the distance between the rows, to plant the seed thicker, and to use a little more fertilizer in order to encourage a larger growth of table-size potatoes. The seed is covered from 2 to 4 inches deep, and it takes about 15 bushels per acre.

"*Amount of Fertilizer:* The quantity of fertilizer applied per acre will vary with its strength, but the usual practice is to apply in the rows from 1,200 to 1,500 pounds per acre, of a grade that averages to test 4 to 5% of ammonia, 6 to 8% of available phosphoric acid, and 7 to 10% of potash. Some farmers favor the higher percentage of ammonia to force growth in our northern latitude, and the higher percentage of potash to benefit the clover crop which follows in rotation. The usual practice in this section is to apply all the fertilizer at time of planting.

Protection from Frost

"*Cultivation:* As soon as the potato tops begin to show, they are covered from 2 to 3 inches deep with dirt with a two-horse hoe. This is called 'covering,' and protects them from frost. Besides the potatoes seem to come up stronger than where it is not done. When the covering is finished, we begin to cultivate deeply between the rows; and when the vines are about 3 inches high, we ridge the earth up with a two-horse hoe. This is called 'hilling.' About a week or ten days later, we hill again, piling more earth around the stalks. We keep the cultivator going between each hilling, and finally, when the tops are too high for a two-horse hoe, we use a one-horse spade plow which throws the dirt both ways; and this ends the cultivation.

Spraying Keeps Crop Growing Longer

"*Spraying:* We begin to spray when the potatoes are 6 to 8 inches high, using Bordeaux Mixture, and continue it during the season,—in all, about six or seven times. During the first two or three sprayings, we add poison to kill the potato bugs. If well sprayed, the tops keep green and growing until the frost kills them, which is about the 20th of September.

"*Harvesting:* The potatoes are dug with a two-horse digger, beginning about the 1st of September. They are

picked up by hand, but those smaller than hens' eggs are left on the ground and afterwards taken to starch factories. The marketable potatoes are stored in potato houses built for the purpose, and during the winter are sorted and hauled to market."

It should be added that the above practice will probably not be applicable to all sections of the country. In many sections it is found best not to apply all the fertilizer in one way, but about one-half broadcast and the remainder in the furrows.

Potatoes

Usual Method: A large potato crop absorbs a large amount of plant food. As potatoes make the best part of their growth in sixty days, the manure or fertilizer must be in an available condition, especially when the tubers are forming. For that reason fertilizers are found better for potatoes than stable manure. As a rule, a properly made fertilizer for potatoes will produce tubers that are fair, smooth and mealy.

It Pays to be Generous with the Potato Crop

If the soil is naturally rich or has been made so by previous use of manure or a green crop plowed under, 800 to 1,200 lbs. of a high-grade potato manure will be sufficient for an acre, applied in the furrows and mixed thoroughly with the soil before the seed is dropped. If no manure is applied, or green crop plowed in, apply from 1,200 to 1,500 lbs. per acre. If the potatoes are planted in hills, a small handful should be sprinkled (not dropped) in each hill, mixed and covered with soil. Many potato growers find it profitable to use from 1,500 to 2,000 lbs. per acre, depending on the quality of the fertilizer, character of soil and previous treatment, one-half applied broadcast and the remainder strewn along the furrows.

Indian Corn, Sweet Corn and Ensilage

Corn a Nitrogen Gatherer

Corn is both a grain and a forage crop. It rarely fails if it has sufficient plant food It possesses an extensive root system and is no doubt a nitrogen gatherer, for it thrives best in hot weather when bacterial action is greatest in the soil, but before the hot weather sets in, and later when the crop is maturing, it must be nourished with active plant food.

If grown exclusively on fertilizers, apply from 800 to 1,600 lbs. per acre, depending on the strength of fertilizer, soil, etc. Sow three-fourths broadcast and harrow it into the soil, applying one-fourth in the hills or drills and thoroughly mix and cover with soil. Or all of it may be applied with a modern farm drill if all the tubes are left open. If the soil is poor or run out, a larger quantity should be used. When planting on greensward, 600 lbs. per acre will be sufficient, especially if the sod is a heavy one and was turned over in the spring.

Fertilizer for corn should be used in the same way as manure, —that is, a larger quantity on a poor field and a smaller quantity on a rich field. If manure is used in connection with fertilizer, spread the manure broadcast before plowing and wheel-harrow or plow it in, applying the fertilizer in the furrows or drills, thoroughly mixing it with the soil. If the corn does not come forward for any cause, like a cold, wet spring, 200 or 300 lbs. may be hoed or cultivated in at the first or second hoeing.

Small Grains (Wheat, Rye, Oats, Barley and Buckwheat)

Grains are Shallow Feeders

Apply from 400 to 600 lbs. per acre, depending on the strength of fertilizer, character of soil, etc. As small grains are shallow feeders, we recommend that the fertilizer be drilled in with the seed, allowing the fertilizer to run in all the tubes, provided the drill sows the fertilizer in advance and covers or mixes it with earth so that the seed does not come in contact with clear fertilizer. If the grain is sown broadcast, then sow the fertilizer broadcast in advance of seeding.

Top Dressing Grass and Other Crops

Soluble Fertilizers for Surface Dressing

Chemically prepared fertilizers, those which are soluble and available, are no doubt better for a surface dressing than stable manure, because they dissolve with the first rains or heavy dews and immediately enter the soil and begin to nourish the crop, whereas manure applied on the surface is exposed to waste. Grass takes from the soil a large amount of plant food, which is usually applied in the spring months, although it is often put on after haying for the rowen crop. Apply from

400 to 600 lbs. per acre, sown broadcast. The true principle of manuring mowing lands and pastures, especially on light leachy soils, is to apply a little at a time and often; that is, to top dress with a moderate quantity at least twice during the season.

Top Dressing Winter Grains

Use a Soluble Fertilizer

In the spring, after a particularly hard winter, it is often necessary to apply something to bring the crop along. The best thing for this purpose is a soluble, active fertilizer. It will promote vigorous, early maturity and often turn expected failure into success. Apply from 200 to 400 lbs. broadcast when the leaves are dry.

Seeding or Stocking Down Land

Insure the Catch

There is no doubt that stable manure is an excellent kind of fertilizer for stocking down land, chiefly because it adds humus to the soil and is slower in its effects. For that reason, we recommend using stable manure liberally for seeding down, and fertilizers on hoed crops. It is best, however, to use a little quick-acting fertilizer with the manure in order to *insure* a good catch,—in other words, to feed the young grass roots, which are shallow feeders, before the manure is decomposed and ready to nourish. For this purpose apply from 200 to 400 lbs., sown broadcast and lightly harrowed or brushed into the soil before the seed is sown. If no manure is applied, use from 600 to 1,000 lbs. per acre.

Fodder Crops (Hungarian, Millet, Peas, Oats, Barley, etc.)

Used for Soiling or to be Cured: Apply from 400 to 600 lbs. per acre, broadcast, harrowed into the soil just before the seed is sown.

Roots

It is true, although not usually believed, that 90% of roots, like beets, etc., is water. Growth of this kind is in fact concentrated leaf growth underground and requires a large

amount of fertility in active form to supply the needed plant food for best development. Most roots, although having a comparatively small root system, are quick growers, hence fertilizers are especially successful on roots. Apply from 600 to 2,000 lbs. per acre, depending on the kind grown, the character of the soil and the fertilizer used. Small roots like turnips and carrots do not require as much fertilizer as large roots, like mangolds and rutabagas. The fertilizer is generally sown broadcast, although for roots which are grown in drills the fertilizer should be strewn along the furrows and back-furrowed before the seed is sown; or it can be applied at the same time the seed is sown, if it is thoroughly covered and mixed with the soil so that the seed does not come in contact with it. If it is drilled in with machines which do not mix and cover the fertilizer, it must be diluted with twice as much dry earth or plaster before using, for the seeds of root crops are very tender.

Larger Roots Need More Fertilizer

Onions

If there is any crop which needs an active fertilizer, it is the onion crop, for if it does not grow vigorously it is likely to be strong in flavor and tough in texture. The onion is a bulb with small feeding roots—an aggregation of leaves which grow underground—and requires a great deal of quickly available nourishment. If no manure is applied, use from 1,500 to 2,000 lbs. per acre, sown broadcast and harrowed into the soil, the quantity of course depending on the character of the soil and the strength of the fertilizer. As onions are difficult to weed, and as fertilizer contains no weed seeds, it is a favorite dressing for onions as well as for most market garden crops, or wherever clean culture is necessary.

No Weed Seeds

Cabbage and Cauliflower

These crops are gross feeders and quick growers; they also have a good root system; therefore they need an abundance of available plant food. For cabbage, apply from 1,800 to 2,500 lbs. per acre; for cauliflower, from 1,500 to 2,000 lbs. One-half of the fertilizer may be sown broadcast and harrowed into the soil, and the remaining half strewn where the plants are set, or it may

Gross Feeders

be hoed in about the plants after they have been set. If some stable manure is used, the quantity of fertilizer can be reduced. The manure should be applied broadcast and harrowed into the soil, and the fertilizer applied about the plants.

Celery and Lettuce

There is no question but that commercial fertilizers improve the quality of celery and lettuce. To be tender and crisp, these crops must grow quickly. It is conceded that the most tender and succulent growths are those which are rapid and continuous, and this is what well-made fertilizers will produce under right conditions. For lettuce, apply at the rate of from 400 to 600 lbs. per acre to the seed bed a little time before the seed is sown. When the plants are transplanted or pricked out, apply from 1,000 to 1,500 lbs. per acre, a portion broadcast and a portion around the plants at hoeing time. For celery, apply (if no manure is used) from 1,200 to 2,000 lbs. per acre, one-half when the plants are transplanted, along the furrows, and the remainder when the celery is banked up.

Tender, Crisp Growth Required

Vines (Squashes, Melons, Cucumbers, etc.)

Nearly all crops which produce large, pulpy growth need rich and forcing manures. They are frequently grown on composted manure or night soil, but without these, commercial fertilizers are found equally as good. If any manure is used, apply from 1,500 to 2,000 lbs. per acre, two-thirds broadcast, worked into the soil three or four inches deep, and one-third sprinkled in the hills, about one pint to each hill, thoroughly mixed with the soil before the seed is dropped. If stable manure is used, apply it broadcast, and sprinkle the fertilizer in the hills.

Tomatoes

The tomato belongs to the same family as the potato, and, like the potato, requires a rich soil or a rich fertilizer. If no manure is used, apply from 1,500 to 2,000 lbs. per acre, one-half sown broadcast and worked into the soil and the remainder in the hills thoroughly mixed with the soil before setting the

Rich Fertilizer Required

plants. That which is sown broadcast should be cultivated into the soil at least three inches deep.

Asparagus

"*The American Agriculturist*" states:

The Weed Growth

> "New Jersey growers of asparagus have found out what Southern growers were long ago compelled to put into practice,—that commercial fertilizers are far better for asparagus than stable manure; not that stable manure will not make fine asparagus, but because of the impossibility of keeping down the weed growth when manure is used."

Asparagus needs active, forcing plant food, which manure does not supply unless it has been composted. Probably nine-tenths of the asparagus is grown on commercial manures which produce the succulent, tender growth desired. In starting new plants or making new asparagus fields, apply from 600 to 800 lbs. per acre in the drills or furrows, very thoroughly mixed with the soil. To old fields apply, early in the spring, from 1,200 to 2,000 lbs. per acre between the rows and cultivate it in.

Peas and Beans

Less Nitrogen Required for Legumes

Peas and beans belong to the clover family (legumes), and do not require as much fertilizer, or at least a fertilizer as rich in nitrogen, as do most other crops. Therefore, an application of 500 to 1,000 lbs. of fertilizer rich in phosphoric acid and potash, sown broadcast and harrowed into the soil, is usually sufficient for peas and beans. These crops have an extensive root system and will gather plant food in every part of the soil and especially deep in the soil. It is known that alfalfa, which belongs to this family, will send down a root 20 or 30 feet for water, putting out lateral feeders at upper levels. For this reason peas and beans, the clovers and alfalfa are great "catch" or "cover" crops, and are valuable in rotation.

Strawberries and Small Fruits

Stable manure is a pretty good thing with which to start a strawberry bed, but after it is started, active fertilizers are needed to encourage a rapid growth. The strawberry is an

aggregation of innumerable seeds gathered into a cluster or pulp which is composed chiefly of water and sugar. Nevertheless, a good deal of nourishment is required to produce the root and leaf growth and small seeds essential to fruiting. When the strawberry bed is prepared, apply broadcast from 500 to 1,000 lbs. per acre; then in the spring, between the rows, apply broadcast 500 to 1,000 lbs. more, taking care to keep it off the vines. This appli-ation should be cultivated or hoed in if possible.

Grapes, Currants, etc.

For grapes and currants, apply (if no manure is used) from 1,000 to 1,500 lbs. per acre between the rows, cultivated into the soil. For raspberries and blackberries, apply from 600 to 800 lbs. per acre, cultivated deeply into the soil.

Tobacco

The Form of Plant Food is Important

Tobacco is probably the most exhaustive crop that is grown. It is a ravenous feeder. It will thrive on anything that furnishes plant food. Stable manure, animal tankage, or fish scrap will produce a large, coarse leaf growth, but it has been found that chemically prepared fertilizers, especially if adapted to the crop, will produce not only a good yield, but a leaf of finer texture and color. It is a crop requiring special fertilizers and special methods of cultivation.

If no manure or ashes are applied, we recommend from 1,500 to 2,500 lbs. of fertilizer per acre, one-half applied at the time when the plants are set out, and the remainder between the rows at hoeing time, taking care that none of the fertilizer gets upon the leaves. If not convenient to do this, then apply all of the fertilizer just before the plants are set out, working it into the soil with a wheel harrow. If part stable manure is applied, then use the fertilizer along the drills where the plants are set out, to force the growth of the plants, applying from 500 to 1,000 lbs. per acre, depending on the amount of manure and the strength of the fertilizer used. Even if manure is used, some fertilizer is essential to hasten maturity.

Fruit Trees and Shade Trees

A fertilizer for orchards, as is now well known, should be rich in nitrogen as well as in potash and phosphoric acid, for the skin

and the seed of fruits are more exhaustive than was formerly supposed. Besides, the tree has to grow and mature a large amount of new wood each year. It therefore pays to manure orchards generously with a well-balanced fertilizer. For fruit trees, such as apples, pears, peaches, and plums apply early in the spring at the rate or 5 to 25 lbs. to each tree, according to size, broadcast around the trees, extending out as far as the branches reach. If possible, cultivate it deeply into the soil. If grass is growing under and between the trees, an additional quantity should be applied to supply what the grass will necessarily absorb. Apply about 5 lbs. to trees that are three or four inches in diameter, increasing the quantity up to 25 lbs. for trees that are ten, fifteen and twenty years from setting. For shade trees apply in the same manner as for fruit trees. For hardy shrubs, apply from one pint to a quart to each shrub, or at the rate of 10 lbs. to 200 square feet of border, worked into the soil evenly and thoroughly.

Fruit Trees Need Plant Food as do Hoed Crops

Lawns, Flower Beds and Kitchen Gardens

As fertilizers are free from weed seeds, there is nothing so good for seeding down a lawn or for top-dressing a lawn as a well-made, well-balanced fertilizer. In preparing a new lawn, apply from 1,000 to 1,500 lbs. per acre sown broadcast and cultivated into the soil, before the seed is sown. For top dressing an old lawn, apply from 400 to 800 lbs. per acre broadcast. To get it on evenly, it is advisable to apply one-half walking north and south and the remainder east and west. For flower beds, apply it at the rate of about 10 lbs. to 400 square feet, mix thoroughly with the soil, or cultivate it carefully around the plants, care being taken not to get it in contact with the leaves or young roots.

Flower Beds

There is nothing equal to a well-balanced, complete commercial manure for a kitchen garden. It produces the quick, tender, juicy growth which is desirable in garden vegetables; but a kitchen garden should contain sufficient humus to retain moisture and promote that fine tilth so desirable in a garden. For that reason stable manure should be applied once in three or four years, although it will add weed seeds to the garden, which is avoided in the use of fertilizers. We recommend for kitchen gardens an application at the rate of one ton to the acre

Kitchen Gardens

when no manure is applied. When manure is used, we recommend from 400 to 600 lbs. per acre applied in the hill or drill.

Caution: Fertilizer should never be dropped in its clear state in contact with seed, young roots, or green leaves.

Special Crops

We have not included directions for use on special crops, such as Cotton, Rice, Peanuts, Citrus Fruits, Pineapples, Sugar Cane, etc., as these crops are specialized and cultivated only in sections where soil and climatic conditions are favorable. Broadly, it may be said that the same general principles apply in the fertilization of these crops as in those crops treated in detail in this book. To those crops which make a large, quick growth of foliage and fruit, with large root systems, apply a generous quantity of fertilizer, broadcast or drilled in advance of planting. For those crops with small root systems and which are less exhaustive, a smaller quantity of fertilizer may be used and all of it may be applied in the hill or drill.

General Principles Apply

Commercial "Valuations"

and

Government Regulation

We are often asked why the commercial valuations of fertilizers do not equal the selling prices. Perhaps the best way to answer this question is to quote from the State officials who make these valuations.

What Directors Say

Director Jenkins of the Connecticut Experiment Station writes:

Connecticut

> "The 'Valuation' only aims to show the actual cost at freight centers of the plant food in the goods, and not at all the *fair* price at retail of the mixed and ground goods. This fair retail price must in all but exceptional cases be considerably higher than the valuation. The 'valuation' *excludes* all of the manufacturer's expenses for interest, depreciation, mixing, bagging, freight, commissions and bad debts,—expenses which make the profit of the manufacturer in few cases unreasonable and *in some cases a minus quantity.* It is an abuse of figures to use our valuations in any other sense than as above explained."

In the Massachusetts Bulletin on "Commercial Fertilizers" (1908), we find the following statement with reference to valuations:

Massachusetts

> "This (difference), commonly called 'overhead charges,' represents the cost in storing, grinding, mixing, bagging, hauling and freighting the goods, as well as commissions to agents, long credits, depreciation of factory plant, and profits. It is not surprising, therefore, that valuations fall below the retail cash prices."

In the Vermont Bulletin on "Commercial Fertilizers" (1909), Director Hills writes:

Vermont

> "Some buyers construe this sum (the difference between valuation and selling price) to be the manufacturer's profit. Such a construction is utterly unwarranted and only explicable on the assumption that in no way whatsoever

have they made the slightest effort to grasp the fundamental idea of the valuation system. Only a fraction of this sum represents profit. Its main items are freight rates, and factory and sales charges. It were quite as logical to assume that the difference between the retail cost of a pair of shoes and the raw leather from which they were made were all profit. Selling prices always exceed valuations, since the latter show only the seaboard values of the unmixed ingredients and do not include the many other necessary and legitimate charges which accompany the manufacture and sale of mixed goods."

Cost of Selling Fertilizers and Milk Compared

We could quote from many other State fertilizer reports, explaining in the same way the difference between the official valuation of fertilizers and the selling price. In a word, the difference between the cost of the raw materials at the seaboard and the delivered selling price for the finished goods in the country covers certain fixed expenses which must be met before profits can be considered. These expenses are for assembling the materials, grinding, chemically treating them, shrinkage, interest (90% of the goods are sold on "crop time"), bags, freight, wear and tear (which is heavy in a chemical plant), commissions to agents and finally interest on capital employed. The unit cost of a quart of milk may not be over two cents for the grain and hay consumed by the cow, but every farmer knows that he could not afford to peddle milk at two cents a quart. He must have something to cover the cost of labor, loss of animals, wear and tear of team in delivering milk, bad debts, etc.

Quantity and Quality Considered

Several States which formerly employed the "valuation system" have abandoned it as being not only unsound, but misleading, because usually misconstrued. For example: Many farmers construe valuations as representing not only commercial value in the country, but agricultural or crop-producing value, which is far from right in either case. According to the inspector's report, two fertilizers may value approximately alike, but one may be worth very much more as a crop producer than the other. The reason for this is, that while the analysis of the fertilizer shows the *quantity*, it does not reveal the *quality* or *crop value* of the plant food which it contains, and on that account no valuation can represent either the true commercial or the agricultural worth. Two cows standing side by side in a barn may

be worth approximately the same money for beef, but the milk from one may be much richer than the milk from the other and greater in quantity. No basis of commercial valuation is sound that does not take into consideration all the factors that influence it.

Furthermore, as the "difference" between value and selling price is more or less dependent upon local conditions, such as cost of freight, hauling from station, storing, etc., and as this difference may be further modified by the profit charged by the local agent, it seems unfair to subject the manufacturer to criticism for the difference, since it is absolutely beyond his advice or control. To go further and make these "differences," without knowing all the factors, the basis for Government comparison, we believe is likely to be misleading to the consumer as well as unjust to the manufacturer, thus defeating the object of the law, which in language and in execution should aim to protect all interests.

Difference beyond Control of Manufacturer

Finally, our own view is, that even if all the factors influencing value could be determined, "commercial valuations" would still be wrong in principle, for the reason that the principle was early established that the Government would assume to value merchandise only for purposes of taxation, *never for comparison in commercial transactions*. If, however, the principle is right, why should it not be applied to all lines of business? Why should not milk, butter, cheese, hay, grain, woolen cloth and rubber goods be "valued" by State inspectors for purposes of comparison?

We want it understood that we are strongly in favor of fertilizer laws, of official sampling, analysis, and publication of results,—in a word, of the most thorough Government inspection. It is a great safeguard to the business, it protects the honest manufacturer as well as the consumer; but Government regulation should begin and end with inspection, as in other lines of business.

Government Regulation